NATIONAL BUREAU OF STANDARDS REPORT

6144

Progress Report

on

PROPERTIES OF DENTAL GOLD ALLOY CASTING INVESTMENTS

by

Joseph J. Barone
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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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U. S. DEPARTMENT OF COMMERCE
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PROPERTIES OF DENTAL GOLD ALLOY CASTING INVESTMENTS

Abstract

Properties of dental gold alloy casting investments were measured and test procedures were developed as a basis for development of specifications for these materials. Values for the fineness, consistency, setting time, expansion and compressive strength of the thermal expansion inlay, hygroscopic expansion inlay and thermal expansion partial denture types of investment were determined. Although wide variations between the properties of different investments of any one type were observed, group differences between types were slight. The results indicate that data on setting expansion in air and in water as well as on thermal expansion are needed in order to produce precision dental castings.

1. INTRODUCTION

In addition to dental inlay casting investment for gold alloys as described in American Dental Association Specification No. 2, July 1930 [1] and in Federal Specification U-I-546a [2] two other types of gold alloy casting investments, namely, inlay hygroscopic investment and partial denture or model investment, are widely used in dentistry. It was the purpose of this study to determine the physical properties of investments

of these three types and to develop new test procedures or modify existing procedures for use in specifications for these materials. For ease of discussion and according to technic employed the investments are classified into types as follows: Type I - thermal inlay investment, Type II - hygroscopic inlay investment and Type III - thermal partial denture investment. In order to coordinate the age of test specimens in general with the age of the material as used in practice and to facilitate laboratory testing procedures most of the tests were made within approximately two hours after the investment was mixed rather than at the one day or seven day times which have often been used previously.

2. MATERIALS INVESTIGATED

Data were obtained on 14 brands of investment, one of which was recommended for both Type I - thermal inlay and Type II - hygroscopic inlay use and four of which were recommended for both Type I and Type III - partial denture use. All of the materials included are listed by brand name, type, batch number and manufacturer in Table 1. The order of listing of materials in Table 1 is not related to the order of listing in the tables of physical properties.

3. EXPERIMENTAL PROCEDURE AND RESULTS

3.1 Fineness

The fineness of the investment powder was determined by screening 10 gram specimens through 8 inch diameter sieves numbers 30, 100 and 200 stacked from top to bottom in that order.

The sieves conformed to Federal Specification RR-S-366b. Before sieving, the sample was spread out in a thin layer at 45°C and then cooled in a desiccator over anhydrous $CaSO_4$ (Drierite). The 10 g specimen was then brushed through the sieves with as little abrasion as possible and the material retained on each sieve was weighed. The results are given in Table 2.

A more convenient, simplified method of sieving capable of producing equally consistent reproducible results was sought after. Though the hand sieving technic with near frictionless brushing of a 10 g specimen through the sieves was adopted for testing, mechanical sieving using the Tyler Ro-Tap Testing Sieve Shaker was also tried. The chief difficulty encountered with mechanical sieving was the "balling up" of the fine powder and the clogging of the sieve mesh particularly on the number 200 sieve. Another method of sieving which showed promise was a comination of hand and mechanical sieving. By placing the sieves on a vibrating dental type vibrator (particularly one with a variable control) and brushing the material through the sieves with as little friction as possible, somewhat more rapid sieving was possible.

3.2 Testing Consistency

The American Dental Association Specification No. 2 consistency test, though modified, served as the method for testing consistency in this study. The test, briefly, is lifting a cylindrical mold (2 inches long with an internal diameter of

1-3/8 inches) two minutes after start of mix so as to allow the test mixture contained in the mold to slump or spread over a plate on a vibration-free bench. The powder is added to the water, hand spatulated for twenty seconds and mechanically spatulated for twenty seconds. The major and minor diameter of the slumped mixture are measured one minute after the cylinder is lifted.

The water/powder ratios were adjusted until the average of the maximum and minimum diameters of the slumped specimens were between 2-1/4 and 2-3/4 inches for Types I and II and between 1-1/2 inches and 1-5/8 inches for Type III investment. In the case of each type of investment the test consistency limits were set close to the consistency limits produced when using the manufacturer's recommended W/P ratio in the directions furnished with the investment. The outer limit of slump for Type I and Type II inlay investment has been set at 2-3/4 inches rather than at 3 inches as given in American Dental Association Specification No. 2 because of the improved physical properties usually associated with a thicker consistency. The curves plotted in Figures 1 and 2 demonstrate the variation of slump diameter values with water/powder ratio for Type III investments.

The consistencies determined and used in making specimens for setting time, compressive strength and expansion determinations are given in Table 3. The manufacturers' recommended consistencies are also given in Table 3 for comparison with the experimentally determined consistencies used in making test specimens.

3.3 Time of Setting

The time of setting was determined with a Vicat needle. The specimen was made from a mix containing not less than 100 grams of powder and was placed in a cylindrical mold 1-3/4 inches in diameter by 2-1/8 inches in height. Results are given in Table 4. As would be expected, for those materials mixed at both Type I and Type III consistencies, the setting time was less for thicker mixes (lower water/powder ratios).

3.4 Expansion

The change in length on setting was determined on specimens approximately 30 centimeters long by observing the change with a micrometer microscope comparator. The specimens were poured in a V trough lined with dental rubber dam. Small brass plates on which cross lines had been ruled were placed 30 centimeters apart in the investment specimen to serve as reference points for observation with the microscope comparator. The initial and final readings for setting expansion were made at 5 minutes and at 2 hours, respectively, after start of mix. Hygroscopic setting expansion specimens were immersed in water immediately after the initial reading.

Thermal expansion was measured on specimens approximately 1.2 centimeters in diameter by approximately 20 centimeters in length by the "Fused Quartz Expansion Apparatus" method [3]. Specimens were gradually heated from room temperature at a constant rate to 500°C for Type II investments and 700°C for Types I and III. The initial reading was taken and heating was started two

hours after the beginning of the mix.

Results for both setting and thermal expansion are given in Table 5. Setting expansions in air ranged from 0.2% to 0.5%. Different brands of investment showed a wide range of hygroscopic or setting expansions in water varying from 0.3% to 1.7%. It was noted that the highest hygroscopic expansion observed was for an investment recommended for a thermal rather than a hygroscopic technic. Conversely, one of the Type II hygroscopic investments exhibited a rather low, 0.8%, hygroscopic expansion and a relatively high, 0.8%, thermal expansion at 500°C.

3.5 Compressive Strength

The compressive strength of the investment was determined on five cylindrical specimens one inch in diameter and two inches high. The specimens were crushed at a loading rate of 400 pounds per square inch per minute when they were 2 hours old. In computing the average strength, any cylinder whose strength varied more than 15% from the average was discarded. In case three or more cylinders varied more than 15 percent from the average, the lot was discarded and the test repeated.

Table 6 lists the compressive strength values obtained for each investment. It is evident that the consistency of the investment affects its compressive strength. Table 6 illustrates that mixing an investment at Type III consistency increases its compressive strength approximately 25 to 60% over the strength of the same material mixed at Type I consistency.

4. DISCUSSION

The data obtained in this study indicate that the properties of the three types of investment, thermal expanding inlay, hygroscopic expanding inlay and thermal expanding partial denture, are similar in many respects. Differences in properties which were observed depended to a considerable extent upon the technic of handling the investments rather than upon the inherent properties of the materials. This would be expected since some of the materials are recommended for more than one type of casting with technics depending upon the type of use.

The data show that there is no clear cut difference in magnitude of hygroscopic expansion between the group of investments recommended for thermal expansion technics and the group recommended for hygroscopic expansion technics. The high hygroscopic expansion of an investment used in a thermal expansion technic can be a source of dimensional inaccuracy. If an undetermined amount of water from an asbestos liner in a casting ring or from any other source is available to the investment during the setting period it will cause a hygroscopic expansion falling somewhere between the setting expansion in air and the setting expansion in water. The rather low hygroscopic expansion of one investment recommended for a hygroscopic technic indicates that a large part of the necessary expansion of this material is obtained through thermal expansion.

In general, the compressive strengths of Type III - partial denture investments are higher than those of Type I and Type II inlay investments. Examination of the data, however, shows that a large part of this difference results from the lower water to powder ratio used with the Type III materials.

5. SUMMARY

Values for the fineness, consistency, setting time, expansion and compressive strength of investments of the thermal expansion inlay, hygroscopic expansion inlay and thermal expansion partial denture types were determined. Although wide variations between the properties of different investments of any one type were observed, group differences between types were slight. Examples of thermal expansion investments with high hygroscopic expansion and hygroscopic investments with high thermal expansion were found. The data in this study indicate that the users of these investments require exact data on setting expansion in air and in water as well as the thermal expansion for all types of investments in order to produce precision dental castings.

5. BIBLIOGRAPHY

1. American Dental Association Specifications for Dental Materials. Specification No. 2 for Dental Inlay Casting Investment. Page 36. American Dental Association, Chicago 11, Illinois, 1958.

2. Federal Specification U-I-546a, December 17, 1956, U. S. Government Printing Office. Washington 25, D. C. 1956.

3. P. Hidnert, and W. T. Sweeney. Thermal expansion of magnesium and some of its alloys. BS J. Research 1:771 (Nov. 1928). Research Paper 29.

Table 1

MATERIALS INVESTIGATED

Brand Name	Type	Batch No.	Manufacturer
Baker Cristobalite Investment for Inlays and Large Castings	I, III	711014	Baker and Co., Inc.
Baker Cristobalite Investment for Models	III	709203	Baker and Co., Inc.
Baker Hygroscopic Investment	II	705062	Baker and Co., Inc.
Kerr Cristobalite Inlay Investment	I	791RA180	Kerr Mfg. Co.
Kerr Cristobalite Model Investment	III	733RA5316	Kerr Mfg. Co.
R and R Cristo-Vest	I	Lot 7AC	Ransom and Randolph Co.
R and R Gray	I, III	7HO	Ransom and Randolph Co.
Steele's Super Investment	I, III	7EN	Ransom and Randolph Co.
R and R Hygroscopic Investment	II	71D	Ransom and Randolph Co.
S.S.White Inlay Investment Formulas 25	I	Lot 1	S.S.White Dental Mfg. Co.
S.S.White All-purpose Investment Compound Formula 35	I, III	Lot 1	S.W.White Dental Mfg. Co.
Beauty-Cast Inlay Investment	I, II	0825703	Whip-Mix Corp., Inc.
Whip-Mix Cristobalite Model Investment	III	0817701	Whip-Mix Corp., Inc.
Weinstein's Casting Investment	I	908	William Getz Corp.

Table 2

FINENESS

Material	Type	Percent Through Sieve		
		No. 30	No. 100	No. 200
A	I, III	100.0	99.9	94.0
E	I	100.0	99.4	90.9
I	I, II	100.0	99.4	94.9
J	II	100.0	99.0	88.5
K	II	100.0	99.8	98.8
M	III	100.0	94.9	92.3

Table 3

CONSISTENCY - ML of WATER PER 100 G of POWDER

Material	Type I		Type II		Type III	
	Mfr. Rec.	2 1/4-2 3/4*	Mfr. Rec.	2 1/4-2 3/4*	Mfr. Rec.	1 1/2-1 5/8*
	ml	ml	ml	ml	ml	ml
A	31	30			26	25.5
B	31	31			27	28
C	28	29			25	26.5
D	38	37			--	31.5
E	44	42				
F	40	43				
G	32	31				
H	35	37				
I	30	34	30	34		
J			30	31		
K			38	37		
L		(33)**			30	30
M		(35)**			31	31
N		(36)**			31	31

* Average diameter in inches of slumped specimen.

** These materials are not recommended by the manufacturers for use as Type I inlay investments.

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Table 4

SETTING TIME

Material	Type I*	Type II*	Type III*
	Min.	Min.	Min.
A	11.0		--
B	21.2		17.5
C	13.6		13.5
D	17.7		13.7
E	7.3		
F	14.3		
G	12.7		
H	12.8		
I	17.9	17.9	
J		12.8	
K		17.6	
L	(17.6)**		--
M	(13.5)**		8.5
N	(10.6)**		8.4

* Consistency (water/powder ratio) of specimens is given in Table 3.

** These materials are not recommended by the manufacturers for use as Type I inlay investments.

Table 5

EXPANSION

Material	Type I*			Type II*			Type III*		
	Setting Exp.		Thermal Exp. 700°C	Setting Exp.		Thermal Exp. 500°C	Setting Exp.		Thermal Exp. 700°C
	In Air	In Water		In Air	In Water		In Air	In Water	
	%	%	%	%	%	%	%	%	%
A	.29	.38	1.10				--	--	--
B	.20	.28	--				--	--	--
C	.26	.36	1.17				--	--	--
D	.27	.77	1.10				--	--	--
E	.17	.45	.4						
F	.37	1.28	1.32						
G	.47	1.71	1.02						
H	.35	.66	1.27						
I	.43	1.59	1.10	.43	1.59	.42			
J				--	1.11	.27			
K				--	.84	.85			
L	(.36)**	(.85)**	(1.16)**				.37	1.05	1.19
M	(.21)**	(.47)**	(.95)**				--	--	--
N	(.27)**		(.74)**				--	--	--

* Consistency (water/powder ratio) of specimens is given in Table 3.

** These materials are not recommended by the manufacturers for use as Type I - inlay investment.

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Table 6

COMPRESSIVE STRENGTH AT 2 HOURS

Material	Type I*	Type II*	Type III*
	psi	psi	psi
A	1425		--
B	517		731
C	923		1447
D	465		752
E	271		
F	282		
G	479		
H	447		
I	398	398	
J		882	
K		536	
L	(1106)**		1395
M	(658)**		846
N	(645)**		924

* Consistency (water/powder ratio) of specimens is given in Table 3.

** These materials are not recommended by manufacturers for use as Type I inlay investments.

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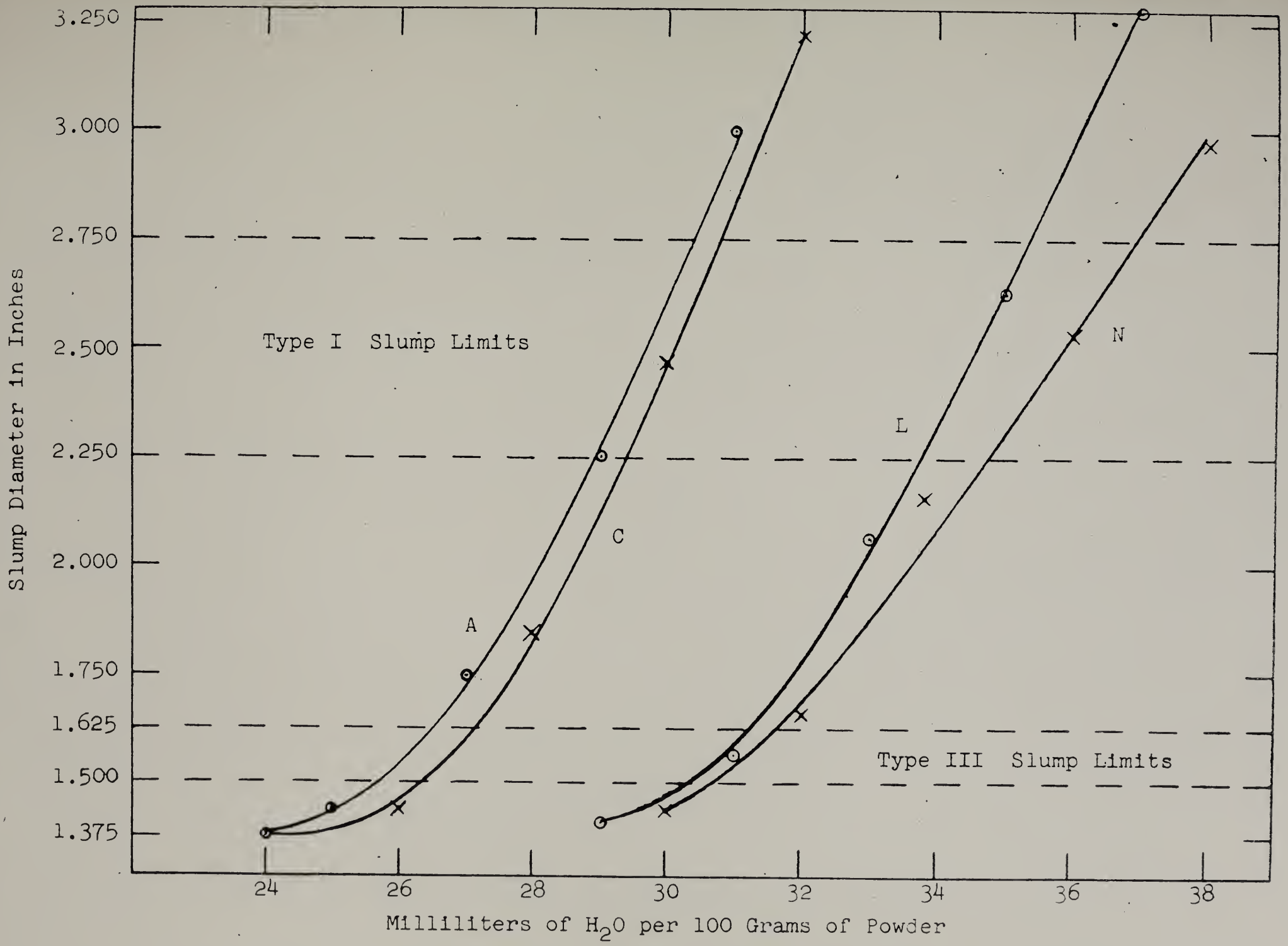

Figure 1. Effect of W/P Ratio Variation on Slump Diameter for Investments A, C, L, N.

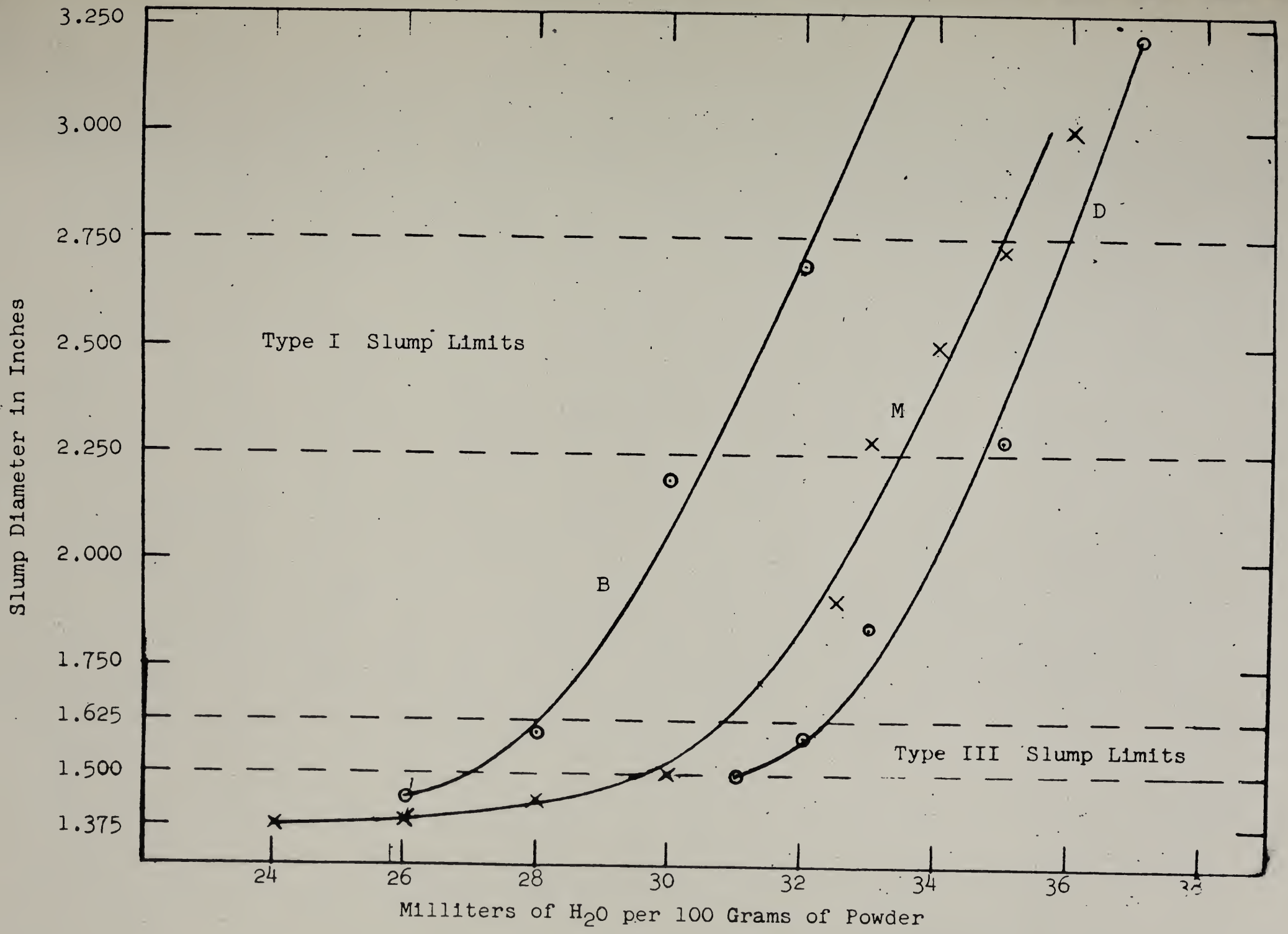

Figure 2. Effect of W/P Ratio Variation on Slump Diameter for Investments B, M, D.

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